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Experimental Study on the Rare Decays $K_L^0 \to \mu e$ and $K_L^0 \to ee$

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Abstract

The purpose of this experiment is to search for the rare decays $K_L^0 \to \mu e$ and $K_L^0 \to ee$. The decay $K_L^0 \to \mu e$ is a lepton flavor changing process which is forbidden by the Standard Model with massless neutrinos. On the other hand, it is predicted to be observed at the order of 10^{-11} to 10^{-12} by some new models such as the Horizontal gauge symmetric model, the Technicolor model. These models might also enhance the decay rate of the decay $K_L^0 \to ee$, while it is highly suppressed, to the order of 10^{-12} in the Standard Model due to GIM mechanism and helicity suppression. Therefore the observation of these decays at an order of $10^{-11}$to 10^{-12} provides a good means to search for new interactions. The sensitivities of this experiment for the decays $K_L^0 \to \mu e$ and ee are about 4×10^{-11} and better than previously achieved.

The experiment was performed using the K0 beam line of the KEK 12GeV Proton Synchrotron. A neutral beam produced by the proton beam with $1.0 \sim 2.5 \times 10^{12} ppp$ was collimated and conducted into a vacuum decay chamber. The K_L^0 decays were detected by a detector system followed by the decay chamber, which consisted of two symmetric arms along the beam line as shown in Fig.1. Each arm consisted of a spectrometer with two magnets and five drift chambers, two hodoscopes, a gas Čerenkov counter filled with air, an electromagnetic shower counter of a lead-scintillator sandwich type and a muon identifier of four iron blocks followed by scintillation hodoscopes. The basic trigger for

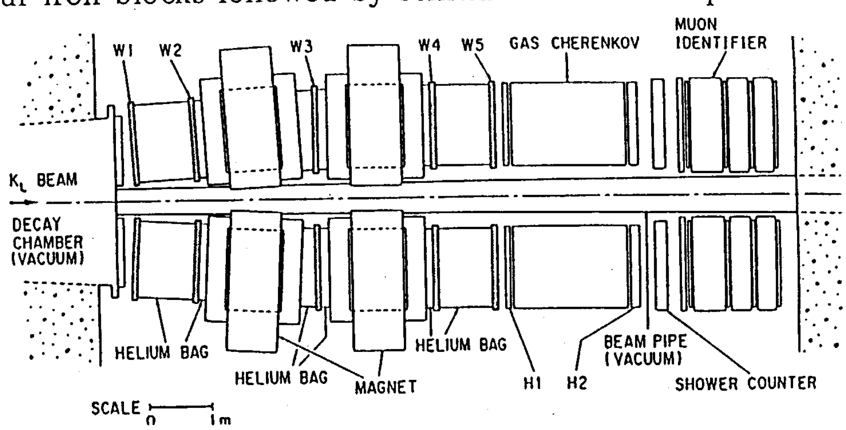

Figure 1: Plan view of the detector system.

the decays $K_L^0 \rightarrow \mu e$ and ee was a coincidence between two hodoscopes in both arms, and additionally lepton-identifier signals were required. In order to obtain the desired sensitivities for the decays $K_L^0 \rightarrow \mu e$ and ee , the decay $K_L^0 \rightarrow \pi^+\pi^-$ with the branching ratio of 2.03×10^{-3} was also triggered only by the hodoscopes. The μe , ee and $\pi\pi$ triggers were acquired simultaneously.

In the off-line analysis track candidates were reconstructed from the hit positions in the drift chamber and hodoscopes. In order to eliminate pions decaying to muons in the spectrometer and reject the background unassociated with the K_L^0 decays, cuts for the track and event qualities were applied to the reconstructed events. Particle identification was further applied to the all selected events. The sensitivities for the decays $K_L^0 \rightarrow \mu e$ and ee were calculated by normalizing to the $K_L^0 \rightarrow \pi^+\pi^-$ events of which 6.80×10^7 were accumulated. The particle-identification efficiencies were calibrated using the semileptonic K_L^0 decays. The sensitivities were obtained to be 4.07×10^{-11} for the decay $K_L^0 \rightarrow \mu e$ and 4.14×10^{-11} for the decay $K_L^0 \rightarrow ee$, respectively.

We have observed no $K_L^0 \rightarrow \mu e$ event in the fiducial region as shown in Fig.2(a). Thus, the upper limit of the $K_L^0 \rightarrow \mu e$ branching ratio at 90% confidence level was determined to be 9.4×10^{-11} with a systematic error of 3%. There were a few background events near to but outside the fiducial region. The background events came from the decay $K_L^0 \rightarrow \pi e \nu$ with the $\pi \rightarrow \mu\nu$ decay in the spectrometer, whose influence on the fiducial region was small enough at this sensitivity. There was one ee event in the fiducial region as shown in Fig.2(b). The event was at the tail end of five background events below K_L^0 mass which mainly came from the decay $K_L^0 \rightarrow e^+e^-e^+e^-$ and could not be distinguished from them at the level of one-event sensitivity. Therefore the upper limit of the $K_L^0 \rightarrow ee$ branching ratio at 90 % confidence level was determined to be 1.6×10^{-10}.

In the scheme of the Horizontal gauge symmetry, the lower limit for the mass of the new gauge boson mediating the decay $K_L^0 \rightarrow \mu e$ was estimated to be $71 TeV/c^2$ from the upper limit of the $K_L^0 \rightarrow \mu e$ branching ratio.

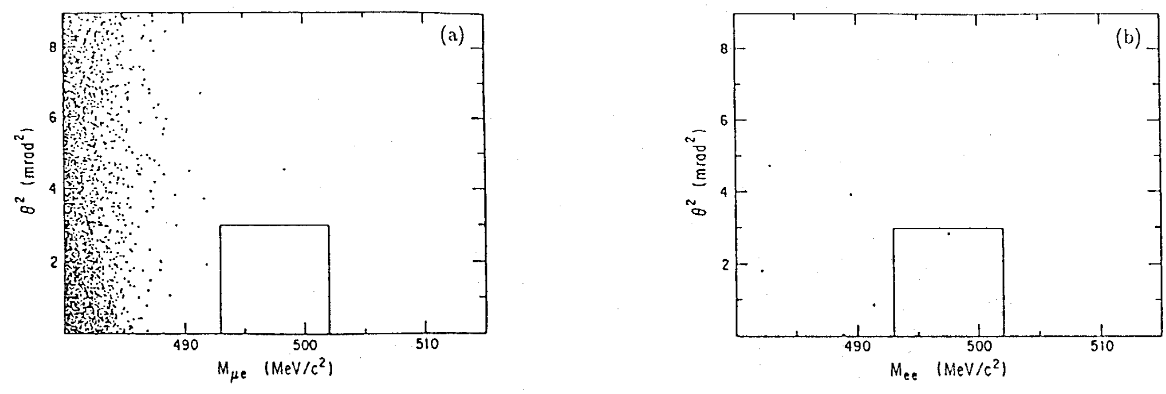

Figure 2: Scatter plots for (a)μe and (b)ee events of the effective mass vs. θ^2. The collinearity angle θ is defined as the angle between the target-to-vertex direction and the K_L^0 momentum reconstructed by the tracking.